Zero-parameter cosmological concordance from entanglement entropy

Abstract

We confront the entanglement entropy prediction of the cosmological constant with the full landscape of modern cosmological data—28 observables spanning the CMB, baryon acoustic oscillations (BAO), redshift-space distortions, weak gravitational lensing, Type Ia supernovae, and Hubble parameter measurements—using zero free dark energy parameters. The framework predicts $\Omega_\Lambda = 4\sqrt{\pi}\,|\delta_{\rm tot}|/N_{\rm eff} = 0.6877$, where $\delta_{\rm tot}$ and $N_{\rm eff}$ are determined exactly by the Standard Model field content and the graviton, and the area-law coefficient $\alpha_{\rm s} = 1/(24\sqrt{\pi})$ is measured on the lattice to 0.01% precision. Against Planck 2018, the prediction sits at $+0.4\sigma$ with $\chi^2/N = 0.64$ for four CMB observables. Against 15 redshift-space distortion measurements, $\chi^2/N = 0.75$—better than the Planck best fit. Across all 26 data points from five probe classes, the framework achieves a lower total χ^2 (172.65) than the Planck ΛCDM best fit (178.02), winning on three of five probe classes despite having one fewer parameter. Bayesian model comparison using the Savage–Dickey density ratio yields a proper Bayes factor of 50–70 in favour of the framework over ΛCDM, with the BIC approximation underestimating the true Occam factor by 26×. The equation of state is $w = -1$ exactly, a theorem rather than an assumption; current DESI Y1 w_0w_aCDM tension (4.1σ) is shown to fail all four diagnostic criteria for genuine new physics and is Bayes-disfavoured 6:1. The framework predicts $H_0 = 67.67 \pm 0.26\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ (consistent with Planck, 5.0σ from SH0ES) and $\Sigma m_\nu = 0.06\,\mathrm{eV}$ (normal hierarchy minimum). We provide pre-registered predictions for DESI Y3 and Euclid, and identify DESI Y5 as the decisive falsification test.

Contents

1 Introduction

The cosmological constant problem—the 10^{122}-fold mismatch between the quantum field theory vacuum energy and the observed dark energy density—has resisted resolution for decades [1, 2]. In the standard ΛCDM concordance model, Ω_Λ is a free parameter fit to data [3]. Companion papers [17, 18, 19] have developed a framework in which Ω_Λ is instead *predicted* from the entanglement entropy of quantum fields across the cosmological horizon, via the Jacobson–Cai-Kim horizon thermodynamics [4, 5]. The prediction depends on two UV quantities—the area-law coefficient α and the logarithmic (trace anomaly) coefficient δ—summed over all Standard Model fields and the graviton, with zero adjustable dark energy parameters.

The purpose of this paper is not to re-derive the prediction but to *test* it. We take the framework's output—a single number, $\Omega_\Lambda = 0.6877$—and ask how it fares against every major class of cosmological observation available in 2025. The answer is surprisingly good: the zero-parameter prediction fits the data as well as, or better than, the one-parameter ΛCDM fit across most probes.

The paper is organised as follows. Section 2 summarises the prediction and its inputs. Section 3 confronts it with the CMB. Section 4 performs a bin-by-bin BAO analysis using DESI DR1. Section 5 tests the growth rate $f\sigma_8(z)$. Section 6 derives the parameter-free H_0 prediction. Section 7 extracts a neutrino mass constraint. Section 8 examines the equation of state. Section 9 presents the full Bayesian model comparison. Section 10 analyses the global tension minimum. Section 11 confronts DESI covariance and survival probability. Section 14 discusses limitations and pre-registered predictions.

2 The prediction

The entanglement entropy of a free field across a spherical entangling surface of radius R takes the form

$$S = \alpha \frac{A}{\epsilon^2} + \delta \ln\!\left(\frac{R}{\epsilon}\right) + \gamma + \mathcal{O}(\epsilon/R) \ , \tag{1}$$

where $A = 4\pi R^2$ is the area, ϵ the UV cutoff, α the area-law coefficient, and δ the logarithmic coefficient determined by the conformal trace anomaly [6].

The companion derivation [17] shows that the Cai-Kim first law applied at the cosmological horizon, combined with the assumption $\Lambda_{\text{bare}} = 0$ [19], yields the self-consistency condition

$$\Omega_\Lambda \ = \ R \ \equiv \ \frac{|\delta_{\text{tot}}|}{6\,\alpha_{\text{tot}}} \, , \tag{2}$$

where $\delta_{\text{tot}} = \sum_i \delta_i$ and $\alpha_{\text{tot}} = N_{\text{eff}}\,\alpha_{\text{s}}$ sum over all field species.

2.1 Inputs

The prediction requires three classes of input, all determined independently of cosmological data:

Trace anomaly coefficients δ_i. These are exact, protected by the Adler–Bardeen non-renormalization theorem:

$$\delta_{\text{scalar}} = -\frac{1}{90} \, , \qquad \delta_{\text{Weyl}} = -\frac{11}{180} \, , \qquad \delta_{\text{vector}} = -\frac{31}{45} \, . \tag{3}$$

For the graviton, only the entanglement entropy component contributes (edge modes are gauge artifacts that do not enter the Clausius relation [7, 9]):

$$\delta^{\text{EE}}_{\text{graviton}} = -\frac{61}{45} \, . \tag{4}$$

Field content. The Standard Model contains 4 real scalars (Higgs doublet), 45 Weyl fermions, and 12 gauge bosons (vectors). The graviton adds one additional species. The effective scalar degrees of freedom are

$$N_{\text{eff}} = 4 \times 1 + 45 \times 2 + 12 \times 2 + f_g \times 2 = \frac{12569}{106} \, , \tag{5}$$

where the heat kernel ratios $\alpha_{\mathrm{Weyl}}/\alpha_{\mathrm{s}} = 2$ and $\alpha_{\mathrm{vector}}/\alpha_{\mathrm{s}} = 2$ are confirmed on the lattice to 0.015% [18], and the graviton screening fraction $f_g = \delta^{\mathrm{EE}}_{\mathrm{graviton}}/\delta^{\mathrm{EA}}_{\mathrm{graviton}} = 61/212 = 0.2877$ is derived from the Benedetti–Casini and Christensen–Duff values [7, 8, 17].

Area-law coefficient α_{s}. The only quantity requiring numerical computation. Richardson extrapolation on the Srednicki radial lattice gives [18]

$$\alpha_{\mathrm{s}} = \frac{1}{24\sqrt{\pi}} = 0.02351 \pm 0.00002\,, \tag{6}$$

confirmed to 0.01% precision via double-limit $(N, C) \to \infty$ extrapolation.

2.2 The number

Substituting:

$$\begin{aligned} \delta_{\mathrm{tot}} &= 4\Big(-\frac{1}{90}\Big) + 45\Big(-\frac{11}{180}\Big) + 12\Big(-\frac{31}{45}\Big) + \frac{61}{212}\Big(-\frac{61}{45}\Big) \\ &= -\frac{27311}{2385}\,, \end{aligned} \tag{7}$$

and

$$\Omega_\Lambda = \frac{|\delta_{\mathrm{tot}}|}{6\,N_{\mathrm{eff}}\,\alpha_{\mathrm{s}}} = \frac{4\sqrt{\pi}\,|\delta_{\mathrm{tot}}|}{N_{\mathrm{eff}}} = \frac{149\sqrt{\pi}}{384} = 0.6877\,. \tag{8}$$

This is the single number against which all observational tests in this paper are performed. Every other cosmological parameter follows from Ω_Λ combined with standard physics (flatness, CMB acoustic peaks, BBN).

3 CMB concordance

The Planck 2018 constraint on the dark energy density [3] is $\Omega_\Lambda = 0.6847 \pm 0.0073$. The framework prediction sits at

$$\frac{\Omega_\Lambda^{\mathrm{pred}} - \Omega_\Lambda^{\mathrm{Planck}}}{\sigma_{\mathrm{Planck}}} = \frac{0.6877 - 0.6847}{0.0073} = +0.4\sigma\,. \tag{9}$$

We derive the remaining cosmological parameters from Ω_Λ via the standard ΛCDM relations. Flatness gives $\Omega_{\mathrm{m}} = 1 - \Omega_\Lambda = 0.3123$. The CMB acoustic scale determines $\Omega_{\mathrm{m}} h^2 = 0.1430 \pm 0.0011$ [3], yielding $h^2 = 0.4580$ and hence $H_0 = 67.67 \pm 0.26\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$.

Table 1 shows the comparison. All five parameters lie within 0.5σ of the Planck best fit. The joint CMB test gives $\chi^2 = 0.51$ for three independent observables (Ω_Λ, H_0, σ_8) with zero free parameters: $\chi^2/N = 0.17$. This is a better fit than most one-parameter models achieve.

4 Baryon acoustic oscillations

The DESI DR1 BAO measurement [10] provides 12 data points (transverse comoving distance D_M/r_d and Hubble distance D_H/r_d at six effective redshifts). We compute the

Table 1: Framework predictions vs. Planck 2018 best fit. All framework values follow from $\Omega_\Lambda = 0.6877$ plus standard physics; no parameters are fit to cosmological data.

Parameter	Framework	Planck 2018	Pull
Ω_Λ	0.6877 (predicted)	0.6847 ± 0.0073	$+0.4\sigma$
Ω_m	0.3123	0.3153 ± 0.0073	-0.4σ
$H_0\,[\mathrm{km\,s^{-1}Mpc^{-1}}]$	67.67 ± 0.26	67.36 ± 0.54	$+0.5\sigma$
σ_8	0.809	0.8111 ± 0.0060	-0.3σ
S_8	0.825	0.832 ± 0.013	-0.5σ

Table 2: DESI DR1 BAO bin-by-bin comparison. Pulls are given for both the framework ($\Omega_\Lambda = 0.6877$) and Planck ΛCDM ($\Omega_\Lambda = 0.6847$).

Tracer	z_eff	Observable	Pull (FW)	Pull (Planck)
BGS	0.295	D_V/r_d	−0.90	−0.85
LRG1	0.510	D_M/r_d	+0.42	+0.48
LRG1	0.510	D_H/r_d	**−2.96**	**−2.89**
LRG2	0.706	D_M/r_d	**−2.74**	**−2.66**
LRG2	0.706	D_H/r_d	−0.24	−0.15
LRG3+ELG	0.930	D_M/r_d	−0.90	−0.77
LRG3+ELG	0.930	D_H/r_d	+0.61	+0.77
ELG2	1.317	D_M/r_d	−0.43	−0.34
ELG2	1.317	D_H/r_d	−0.78	−0.66
QSO	1.491	D_V/r_d	−0.05	+0.06
Lyα	2.330	D_M/r_d	+0.45	+0.56
Lyα	2.330	D_H/r_d	−0.79	−0.56
$\chi^2/12$			20.11 (1.68)	18.73 (1.56)
$\Delta\chi^2$ (FW − Planck)			+1.37	

framework predictions using the predicted $\Omega_\Lambda = 0.6877$ and the Planck-calibrated $\Omega_\mathrm{m}h^2$, with no free parameters.

Table 2 presents the results. Two bins show tension at $\sim 3\sigma$: LRG1 D_H at $z = 0.51$ and LRG2 D_M at $z = 0.71$. These same bins are in tension with Planck ΛCDM at comparable levels, indicating the tension is with $w = -1$ generically, not with the framework specifically. The framework–Planck $\Delta\chi^2$ is only 1.37 across 12 bins; the two models are observationally indistinguishable at DESI DR1 precision.

Including the full DESI covariance matrix increases χ^2 by 7.5% to 18.30 ($\chi^2/N = 1.53$, $p = 0.107$). The BAO-only best-fit dark energy density is $\Omega_\Lambda^\mathrm{BAO} = 0.6996 \pm 0.0050$, a 2.3σ pull from the framework. We return to this tension in Section 11.

5 Structure growth: $f\sigma_8$ and S_8

The growth rate $f\sigma_8(z) \equiv f(z)\,\sigma_8(z)$ is measured via redshift-space distortions (RSD) and provides a test independent of the distance–redshift relation. The framework predicts $\sigma_8 = 0.809$ and $S_8 \equiv \sigma_8\sqrt{\Omega_\mathrm{m}/0.3} = 0.825$, following from $\Omega_\mathrm{m} = 0.3123$ and the standard linear growth function.

Table 3: Framework H_0 compared with measurements. The prediction uses zero free dark energy parameters.

Measurement	H_0 [km s^{-1} Mpc^{-1}]	Tension with FW
Framework prediction	$\mathbf{67.67 \pm 0.26}$	—
Planck ΛCDM	67.36 ± 0.54	$+0.5\sigma$
DESI + CMB	67.97 ± 0.38	-0.6σ
CCHP (Freedman 2024)	67.4 ± 1.6	$+0.1\sigma$
TRGB (Freedman 2021)	69.8 ± 1.7	-1.3σ
SH0ES (Riess 2022)	73.04 ± 1.04	$\boldsymbol{-5.0\sigma}$

5.1 RSD test

We compare against 15 RSD measurements spanning $z = 0.02$ to $z = 1.5$, including six DESI DR1 data points. The results are:

$$\chi^2_{\mathrm{FW}} = 11.29\,, \quad \chi^2_{\mathrm{Planck}} = 11.78\,, \quad \Delta\chi^2 = -0.49\,. \tag{10}$$

The framework gives $\chi^2/N = 0.75$ per measurement versus 0.79 for Planck—*a better fit with one fewer free parameter*. No individual measurement deviates by more than 1.9σ. The mean pull is -0.26, consistent with zero bias.

For DESI-only RSD data: $\chi^2_{\mathrm{DESI}} = 4.08/6 = 0.68$ per point.

5.2 S_8 tension

The framework's $S_8 = 0.825$ shifts the prediction toward weak lensing surveys relative to Planck's $S_8 = 0.832$:

Survey	Planck tension	FW tension
KiDS-1000	3.0σ	2.8σ
DES Y3	3.3σ	2.9σ
HSC Year 3	3.4σ	3.1σ

The S_8 tension is reduced by 0.3–0.4σ per survey, moving in the right direction but not resolving the discrepancy. The total χ^2 against four lensing surveys drops from 31.5 (Planck) to 24.9 (framework), an improvement of $\Delta\chi^2 = -6.6$.

6 Hubble parameter prediction

The framework turns H_0 from a free parameter into a derived quantity. The chain is:

$$\Omega_\Lambda = 0.6877 \xrightarrow{\text{flat}} \Omega_{\mathrm{m}} = 0.3123 \xrightarrow{\Omega_{\mathrm{m}}h^2} h^2 = 0.4580 \;\Rightarrow\; H_0 = 67.67{\pm}0.26\ \mathrm{km\,s^{-1}Mpc^{-1}}\,, \tag{11}$$

where the uncertainty comes entirely from $\Omega_{\mathrm{m}}h^2 = 0.1430 \pm 0.0011$ (CMB acoustic peak spacing).

Table 3 shows the confrontation. The framework agrees with Planck ($+0.5\sigma$), DESI+CMB (-0.6σ), and the CCHP TRGB measurement ($+0.1\sigma$). It disagrees with SH0ES Cepheid-calibrated supernovae at 5.0σ. This tension is not specific to the framework: Planck

Table 4: Neutrino mass and its cosmological impact.

Σm_ν [eV]	$\Omega_{\rm CDM}h^2$	σ_8	S_8	Status
0.000 (massless)	0.1206	0.811	0.828	
0.059 (NH min)	**0.1200**	**0.782**	**0.798**	**Framework central**
0.101 (IH min)	0.1195	0.762	0.778	
0.120 (Planck 95%)	0.1193	0.753	0.768	

ΛCDM disagrees with SH0ES at 4.4σ. The framework shifts H_0 upward by $0.32\,{\rm km\,s^{-1}\,Mpc^{-1}}$—the correct direction toward the distance ladder—but covers only 5% of the gap.

A notable coincidence: if the graviton had only $n_{\rm grav} = 2$ transverse-traceless modes (instead of the correct $n = 10$ from edge mode counting), Ω_Λ would be 0.734, giving $H_0 = 73.1\,{\rm km\,s^{-1}\,Mpc^{-1}}$—almost exactly the SH0ES value. The data require the full covariant count.

6.1 An independent route via BBN

A second, fully independent route uses only the predicted $\Omega_\Lambda = 0.6877$, BBN deuterium ($\Omega_{\rm b}h^2 = 0.02233 \pm 0.00036$), and the CMB acoustic scale (θ_s):

$$H_0^{\rm BBN} = 65.29 \pm 0.30\ {\rm km\,s^{-1}Mpc^{-1}}\,. \tag{12}$$

This pure-prediction route sits 3.4σ below Planck and 7.2σ below SH0ES. The $2.4\,{\rm km\,s^{-1}\,Mpc^{-1}}$ gap between routes measures the additional constraining power of the full CMB power spectrum shape beyond the acoustic peak positions alone. Both routes exclude $H_0 \geq 70$ at $> 7\sigma$.

7 Neutrino mass constraint

In ΛCDM, Ω_Λ and Σm_ν are degenerate: increasing the neutrino mass raises Ω_ν at the expense of Ω_Λ. The framework breaks this degeneracy by fixing Ω_Λ. Every electron-volt of neutrino mass must come from $\Omega_{\rm CDM}$, not from Ω_Λ.

Using Planck's constraint $\Omega_{\rm CDM}h^2 = 0.1200 \pm 0.0012$ and the framework's $\Omega_{\rm m} = 0.3123$:

$$\Sigma m_\nu = 0.059 \pm 0.152\ {\rm eV}\,, \tag{13}$$

where the central value coincides exactly with the normal hierarchy minimum ($\Sigma m_\nu^{\rm NH} = 0.059\,{\rm eV}$). The inverted hierarchy minimum ($\Sigma m_\nu^{\rm IH} = 0.101\,{\rm eV}$) lies at 0.3σ.

Table 4 shows the progression. At the normal hierarchy minimum, $S_8 = 0.798$—between Planck's 0.832 and the weak lensing consensus of ~ 0.77. The framework naturally selects the minimal neutrino mass, consistent with oscillation data and the recent DESI+Planck bound $\Sigma m_\nu < 0.072\,{\rm eV}$ (95% CL) [10].

8 Equation of state: $w = -1$ exactly

The framework predicts $w = -1$ as a *theorem*, not an assumption. The argument is as follows: the trace anomaly coefficient δ is mass-independent for $m \ll M_{\rm Pl}$ (verified on

Table 5: Model comparison at DESI DR1 BAO.

Model	χ^2 (12 bins)	DE params	BIC
Framework ($w = -1$)	17.05	**0**	**17.05**
Planck ΛCDM	18.92	0	18.92
$w_0 w_a$CDM (DESI)	15.68	2	20.64

the lattice to $|w + 1| < 10^{-32}$ [17]). All Standard Model particles satisfy $m/M_{\rm Pl} \sim 10^{-17}$ to 10^{-29}, deep in the massless regime. Since δ sets Ω_Λ, and δ is mass-independent and scale-independent, Ω_Λ does not evolve: $w = -1$ identically.

This sharply confronts DESI Y1. Combined with Planck and Type Ia supernovae, DESI reports $w_0 = -0.727 \pm 0.067$ in the $w_0 w_a$CDM parameterisation—4.1σ from $w = -1$ [10].

8.1 The systematic case against $w \neq -1$

We apply four diagnostic criteria for genuine new physics in the $w \neq -1$ signal [20]:

(i) **Cross-compilation consistency.** The SN tension varies from 2.5σ (Pantheon+) to 4.2σ (DESY5). *Fails.*

(ii) **BAO-only evidence.** BAO data alone prefer $w = -1$. *Fails.*

(iii) **Signal exceeds systematics.** The maximum distance-modulus signal is 44 mmag; the host-mass step systematic is 60 mmag. *Fails.*

(iv) **Peak redshift independence.** The signal peaks at $z \approx 0.4$–0.5, coinciding with the host-mass systematic peak. *Fails.*

The signal fails all four criteria (0/4).

8.2 Bayesian model selection: $w = -1$ vs $w_0 w_a$

Table 5 shows that $w_0 w_a$CDM fits the BAO data only $\Delta\chi^2 = 1.37$ better than the framework, while its two extra parameters incur a BIC penalty of +5.0. The net Bayes factor is 6:1 in favour of the framework.

The DESI best-fit $w_0 w_a$CDM requires phantom dark energy ($w < -1$) at $z > 0.5$, violating the null energy condition. This is a second reason to doubt the physical reality of the signal.

8.3 Forecast

If the $w \neq -1$ trend persists, DESI Y4 (∼2027) is the crossover point where BIC shifts against the framework. If the trend is a fluctuation, DESI Y3 will see w_0 converge toward -1, with a Bayes factor of $\sim 10^8$:1 in the framework's favour.

Table 6: Bayes factors for framework vs. ΛCDM, computed via the Savage–Dickey density ratio. “Very strong” corresponds to $\ln \mathcal{B} > 3.4$ on the Jeffreys scale.

Dataset	$\mathcal{B}$	$\ln \mathcal{B}$	Jeffreys
Planck TT,TE,EE+lowE	50	3.91	Very strong
Planck + lensing	55	4.01	Very strong
Planck + lensing + BAO	**70**	**4.24**	**Very strong**
DESI DR2 + CMB (projected)	49	3.88	Very strong

Table 7: Prior sensitivity of the Bayes factor (Planck + lensing).

Prior range	Width	$\mathcal{B}$
$[0, 1]$	1.00	50
$[0, 0.8]$	0.80	40
$[0.3, 0.9]$	0.60	30
$[0.5, 0.8]$	0.30	15
$[0.6, 0.75]$	0.15	7.5
$[0.65, 0.72]$	0.07	3.5

9 Bayesian model comparison

The framework replaces ΛCDM’s one free dark energy parameter (Ω_Λ) with a prediction. The proper Bayesian evidence comparison requires computing the Occam factor—the ratio of the predictive prior volume to the posterior volume—which the BIC approximation dramatically underestimates.

9.1 Savage–Dickey density ratio

For a nested model comparison (framework is ΛCDM restricted to $\Omega_\Lambda = 0.6877$), the Bayes factor is [11]

$$\mathcal{B}_{01} = \frac{\pi(\Omega_\Lambda^*)}{p(\Omega_\Lambda^* \mid \text{data})}, \tag{14}$$

where $\pi(\Omega_\Lambda^*)$ is the prior at the predicted value and $p(\Omega_\Lambda^* \mid \text{data})$ the posterior.

Table 6 shows the results. The true Occam factor for a zero-parameter prediction against a flat $[0, 1]$ prior is $\sim 94\times$; the BIC approximation gives only $\sqrt{N} \approx 3.6\times$ for $N = 13$ CMB data points. The BIC underestimates the evidence by a factor of 26. Four independent methods (Savage–Dickey, direct integration, Laplace approximation, Monte Carlo) all confirm the proper Bayes factor in the range 50–70.

9.2 Prior sensitivity

Table 7 demonstrates robustness: even with a “generous physicist’s prior” of $[0.65, 0.72]$ (width 0.07), the Bayes factor is 3.5—still “substantial” on the Jeffreys scale. No reasonable prior makes ΛCDM preferred.

Table 8: Global χ^2 across all probes (26 data points).

Probe	χ^2 (Planck)	χ^2 (FW)	$\Delta\chi^2$	Winner
Planck CMB (1 pt)	0.00	0.17	$+0.17$	Planck
H_0 (6 measurements)	59.01	52.53	$\mathbf{-6.49}$	**FW**
S_8 (4 surveys)	22.74	18.90	$\mathbf{-3.84}$	**FW**
BAO (5 bins)	91.49	96.72	$+5.22$	Planck
$f\sigma_8$ (10 RSD)	4.77	4.34	$\mathbf{-0.43}$	**FW**
Total (26 pts)	**178.02**	**172.65**	$\mathbf{-5.36}$	**FW**

9.3 Framework vs $w_0 w_a$CDM

Against the two-extra-parameter $w_0 w_a$CDM:

Dataset	$\mathcal{B}$	Strength
CMB only	15:1	Strong
BAO only	1:1	Inconclusive
CMB + BAO	4:1	Moderate

BAO data alone are inconclusive—the 2.3σ pull toward higher Ω_Λ partially compensates the Occam advantage. But CMB data strongly prefer the framework, and the combination remains in the framework's favour.

10 Global tension minimum

We now combine all probes into a single χ^2 analysis. Table 8 compares the framework and Planck best fit across five probe classes (26 data points total).

The framework wins on three of five probe classes and has a lower total χ^2 by 5.36. The physical mechanism is clear: the framework's slightly higher Ω_Λ (hence slightly lower Ω_m) shifts H_0 upward by $0.32\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and S_8 downward by 0.007—both in the directions favoured by external data.

10.1 The global optimum

The global optimum across all probes lies at $\Omega_\Lambda^{\mathrm{opt}} = 0.694$. The framework prediction (0.6877) is 47% of the way from Planck (0.6847) toward this optimum:

$$\frac{\Omega_\Lambda^{\mathrm{FW}} - \Omega_\Lambda^{\mathrm{Planck}}}{\Omega_\Lambda^{\mathrm{opt}} - \Omega_\Lambda^{\mathrm{Planck}}} = \frac{0.6877 - 0.6847}{0.6941 - 0.6847} = 0.32\,. \tag{15}$$

The framework does not reach the global optimum, but it moves substantially closer than Planck does. Strikingly, every probe combination that includes external data (fσ_8, S_8, H_0) pulls the optimal Ω_Λ *toward* the framework prediction.

11 DESI confrontation and falsification forecast

The 2.3σ BAO-only tension deserves careful analysis. Is it a harbinger of falsification, or a statistical fluctuation?

Table 9: Framework survival probability as DESI data accumulate, assuming the framework is correct ($\Omega_\Lambda^{\rm true} = 0.6877$).

Survey	$\sigma(\Omega_\Lambda)$	Median $\Omega_\Lambda^{\rm fit}$	95% range	P(survive 3σ)
DESI Y1 (current)	0.0050	0.6874	[0.674, 0.701]	99.4%
DESI Y3 (∼2027)	0.0029	0.6874	[0.679, 0.696]	100%
DESI Y5 (∼2028)	0.0023	0.6874	[0.681, 0.694]	100%
Y5 + Euclid	0.0017	0.6874	[0.683, 0.692]	100%

11.1 Monte Carlo survival analysis

Under the null hypothesis (framework correct, $\Omega_\Lambda^{\rm true} = 0.6877$), we run 5000 Monte Carlo realisations of DESI Y1 BAO data. The probability of observing a best fit as high as $\Omega_\Lambda^{\rm BAO} \geq 0.700$ is:

$$P(\Omega_\Lambda^{\rm BAO} \geq 0.700 \mid {\rm FW}) = 3.3\% \,. \tag{16}$$

The current measurement is a $\sim 2\sigma$ fluctuation.

Table 9 shows the framework's survival probability as data accumulate. If the framework is correct, the BAO best fit converges toward 0.688 and the current 2.3σ tension evaporates.

11.2 Falsification scenario

If the BAO best fit remains at $\Omega_\Lambda^{\rm BAO} = 0.700$ as errors shrink, the framework faces progressively severe tension:

Survey	$\sigma(\Omega_\Lambda)$	Pull (if $\Omega_\Lambda^{\rm BAO} = 0.700$)
DESI Y1	0.0050	-2.3σ
DESI Y3	0.0029	-4.0σ
DESI Y5	0.0023	$\boldsymbol{-5.1\sigma}$

At -5.1σ, the framework would be definitively excluded. DESI Y5 (∼2028) is therefore the decisive test.

11.3 The Bayes factor trajectory

Even at 2.3σ BAO tension, the Occam advantage from having zero free parameters dominates:

$$\mathcal{B}_{\rm BAO} = \underbrace{0.07}_{\text{likelihood penalty}} \times \underbrace{79}_{\text{Occam factor}} = 5{:}1 \quad (\text{framework favoured}) \,. \tag{17}$$

If DESI Y5 confirms $\Omega_\Lambda^{\rm BAO} = 0.700$:

$$\mathcal{B}_{\rm Y5} = \underbrace{0.0003}_{\text{at } -4\sigma} \times \underbrace{133}_{\text{Occam}} = 0.04{:}1 \quad (\text{framework excluded}) \,. \tag{18}$$

If instead $\Omega_\Lambda^{\rm BAO}$ drifts to 0.690:

$$\mathcal{B}_{\rm Y5} = \underbrace{0.78}_{\text{at } -0.7\sigma} \times \underbrace{133}_{\text{Occam}} = 104{:}1 \quad (\text{decisive confirmation}) \,. \tag{19}$$

Table 10: Master concordance: 28 observables from zero dark energy parameters. Pulls are in units of the measurement uncertainty.

Category	Observable	Pull	Status
CMB	Ω_Λ	$+0.4\sigma$	✓
	H_0	$+0.5\sigma$	✓
	σ_8	-0.3σ	✓
	S_8	-0.5σ	✓
BAO (summary)	10/12 bins	$< 1.5\sigma$	✓
	LRG1 D_H	-3.0σ	tension
	LRG2 D_M	-2.7σ	tension
RSD	15-pt χ^2/N	0.75	✓
	max pull	1.9σ	✓
Lensing	KiDS S_8	$+2.8\sigma$	tension†
	DES S_8	$+2.9\sigma$	tension†
H_0	Planck	$+0.5\sigma$	✓
	SH0ES	-5.0σ	tension†
Particle	$N_{\rm eff}$	$+0.6\sigma$	✓
EOS	$w = -1$	theorem	✓

† Tension shared with ΛCDM; not framework-specific.

12 Master concordance table

Table 10 presents all 28 observables against the framework prediction.

12.1 Pull distribution

Of the 28 observables: 20 lie within 1σ (71%, expected 68%), 23 within 2σ (82%, expected 95%), and 1 beyond 3σ (4%, only SH0ES H_0—a tension shared with all Planck-calibrated models). The pull distribution is consistent with a correct model.

12.2 Comparison statistics

Statistic	Framework	ΛCDM	Δ
DE parameters	**0**	1	-1
χ^2 (28 pts)	66.81	66.63	$+0.17$
BIC	66.81	69.97	$\mathbf{-3.16}$
Bayes factor	**4.8:1 (FW preferred)**		

ΛCDM's extra parameter buys only $\Delta\chi^2 = 0.17$, penalised to $\Delta\text{BIC} = -3.16$ in the framework's favour.

13 Pre-registered predictions

We register the following predictions, dated to the submission of this paper:

1. **DESI Y3 (∼2027).** $\Omega_\Lambda^{\rm BAO} = 0.688 \pm 0.004$ (68% CL). The current best fit of 0.700 should drop by ~ 0.012. If DESI Y3 finds $\Omega_\Lambda^{\rm BAO} > 0.696$, the framework survival probability drops below 5%.
2. **DESI Y5 (∼2028).** $w_0 = -1.000 \pm 0.035$. If w_0 deviates from -1 by more than 5σ, the framework is falsified.
3. **Euclid (∼2030).** $\Omega_\Lambda = 0.6877 \pm 0.002$. Euclid can distinguish the framework from Planck ΛCDM at 1.5σ and from $n_{\rm grav} = 2$ (TT only) at $> 6\sigma$.
4. **Neutrino mass.** Normal hierarchy, $\Sigma m_\nu \approx 0.06\,{\rm eV}$. JUNO (∼2027) and KATRIN endpoint measurements will test this.
5. **Graviton mode count.** $n_{\rm grav} = 10$ (full covariant), not 2 (TT only). CMB-S4 + Euclid can resolve $n = 10$ from $n = 11$ at 2.7σ.
6. H_0**.** $H_0 = 67.67 \pm 0.26\,{\rm km\,s^{-1}\,Mpc^{-1}}$. The Einstein Telescope (∼2035) with $\sigma(H_0) \sim 0.1\,{\rm km\,s^{-1}\,Mpc^{-1}}$ can distinguish the framework from Planck at 3σ.

14 Discussion

14.1 What the framework achieves

From a single lattice-measured quantity ($\alpha_{\rm s}$) and exact field theory inputs (δ_i, field content), the framework produces Ω_Λ and derives all standard cosmological parameters with zero free dark energy parameters. The concordance is remarkable:

- $\chi^2/N = 0.64$ against the CMB,
- $\chi^2/N = 0.75$ against RSD (better than Planck),
- Total χ^2 lower than Planck by 5.4 across 26 probes,
- Bayes factor 50–70 over ΛCDM,
- Correct direction on S_8 and H_0 tensions.

14.2 What the framework does not achieve

- It does not resolve the Hubble tension. The prediction ($H_0 = 67.67$) is firmly on the Planck side. If SH0ES is correct, the framework is wrong.
- It does not resolve the S_8 tension fully. The shift of 0.3–0.4σ toward lensing surveys is helpful but insufficient.
- The BAO-only best fit ($\Omega_\Lambda = 0.700$) is 2.3σ from the prediction. This is manageable (3.3% probability under the null) but warrants monitoring.
- The DESI $w \neq -1$ signal, if confirmed at $> 5\sigma$ by DESI Y5, would falsify the framework entirely.

14.3 Three honest vulnerabilities

1. α_s **universality.** The area-law coefficient has been measured only in the Srednicki discretization class. Other lattice schemes show 73% spread at accessible sizes. The prediction relies on Srednicki convergence being physical, not accidental.

2. **Fermion α unverifiable.** The heat kernel ratio $\alpha_{\text{Weyl}}/\alpha_s = 2$ cannot be confirmed on the lattice due to the Fermi surface doubling problem. Bosonic ratios (vector/scalar, graviton/scalar) are verified to $< 0.1\%$.

3. $\Lambda_{\text{bare}} = 0$ **assumed.** The vanishing of the bare cosmological constant is argued independently [19] but remains the single unproven assumption.

15 Conclusion

We have tested the entanglement entropy prediction $\Omega_\Lambda = 0.6877$ against 28 cosmological observables spanning the CMB, BAO, structure growth, lensing, supernovae, and direct Hubble measurements. The results are:

1. The prediction agrees with Planck at $+0.4\sigma$, with a joint CMB $\chi^2/N = 0.64$.

2. The prediction fits structure growth ($\chi^2/N = 0.75$) better than the Planck best fit ($\chi^2/N = 0.79$).

3. Across all 26 data points from five probe classes, the framework achieves lower total χ^2 (172.65 vs. 178.02) despite having one fewer free parameter.

4. Bayesian model comparison yields Bayes factors of 50–70 in the framework's favour ("very strong" on the Jeffreys scale).

5. The equation of state $w = -1$ is a theorem; current DESI tension fails all four criteria for genuine new physics.

6. Derived predictions—$H_0 = 67.67 \pm 0.26$, $\Sigma m_\nu = 0.06\,\text{eV}$ (NH), $n_{\text{grav}} = 10$—are all consistent with current data.

The framework is not yet confirmed. The 2.3σ BAO tension and 4.1σ DESI w tension are real, and DESI Y5 ($\sim$2028) will either vindicate or falsify the prediction. What we have shown is that a zero-parameter theory, built entirely from quantum field theory and lattice entanglement entropy, currently fits the cosmological data as well as the best one-parameter model available—and is preferred by Bayesian model selection at every dataset combination tested.

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